

NJDOT Bureau of Research  
QUARTERLY PROGRESS REPORT

Project Title:	<b>A Comparison and Analysis of KA-Band Radar Vs. X-Band Radar</b>			
RFP NUMBER: <b>Project 2007-16</b>	NJDOT RESEARCH PROJECT MANAGER: <b>Edward S. Kondrath</b>			
TASK ORDER NUMBER: <b>4</b>	PRINCIPAL INVESTIGATOR: <b>Allen Katz</b>			
Project Starting Date: 1/ 1/ 2007 <b>Original</b> Project Ending Date: 12/31/2007 <b>Modified Completion Date:</b>	Period Starting Date: 7/ 1/ 2007 Period Ending Date: 9/30/2007			

Task	% of Total	% of Task this quarter	% of Task to date	% of Total Complete
Literature Search	5%	0%	100%	5%
1. Examine the state of development of Ka-band Radar	10%	5%	95%	9.5%
2. Prove/disprove Ka-band Radar is as reliable as X-band radar	30%	30%	90%	27%
3. Statistically validate radar testing approaches	25%	30%	90%	22.5%
4. Develop specifications for Ka-band radar meeting requirements of the Court system	10%	10%	30%	3%
5. Examine the state of development for Laser-band Radar	10%	50%	80%	8%
Final Report	10%	0%	0%	0%
<b>TOTAL</b>	<b>100%</b>			<b>75%</b>

Project Objectives:

1. Examine the state of the art in model development for Ka-band Radar.
2. Prove or disprove that the new technology (Ka-band Radar) is at the least as reliable as the current (X-band radar).
3. Identify data deficiencies and the statistical validity of alternative approaches.
4. Develop specifications and standards for Ka-band radar for all the requirements that are imposed by the Court system to be accepted as an instrument that measures speed.

Added Objectives:

5. Examine the state of the art in model development for Laser-band Radar.

Project Abstract:

This project focuses on the New Jersey State Police commitment to highway safety by enforcing posted speed limits. Effective enforcement of speeding statutes requires measured speed to be accurate and state of the art. This requirement is necessary in order to successfully prosecute by using both moving and stationary radar.

The New Jersey State Police currently utilizes MPH Industries K55 X-band radar units. The New Jersey courts have taken judicial notice as to the scientific reliability of the K55 radar. The advent of new Ka-band Radar technology now allows smaller and safer radar units to be employed. To successfully utilize these new Ka-band Radar units their speed measurement accuracy must be established in a scientific manner that will be accepted by the New Jersey courts.

The purpose of this research project will be to 1) establish a program for testing the performance of the new Ka-band radar units relative to the present K55 radar, 2) monitor the implementation of this testing program, 3) review the test results, 4) provide conclusions on performance and 5) document these conclusions in way the will facilitate the employment of Ka-band radar by the New Jersey State Police.

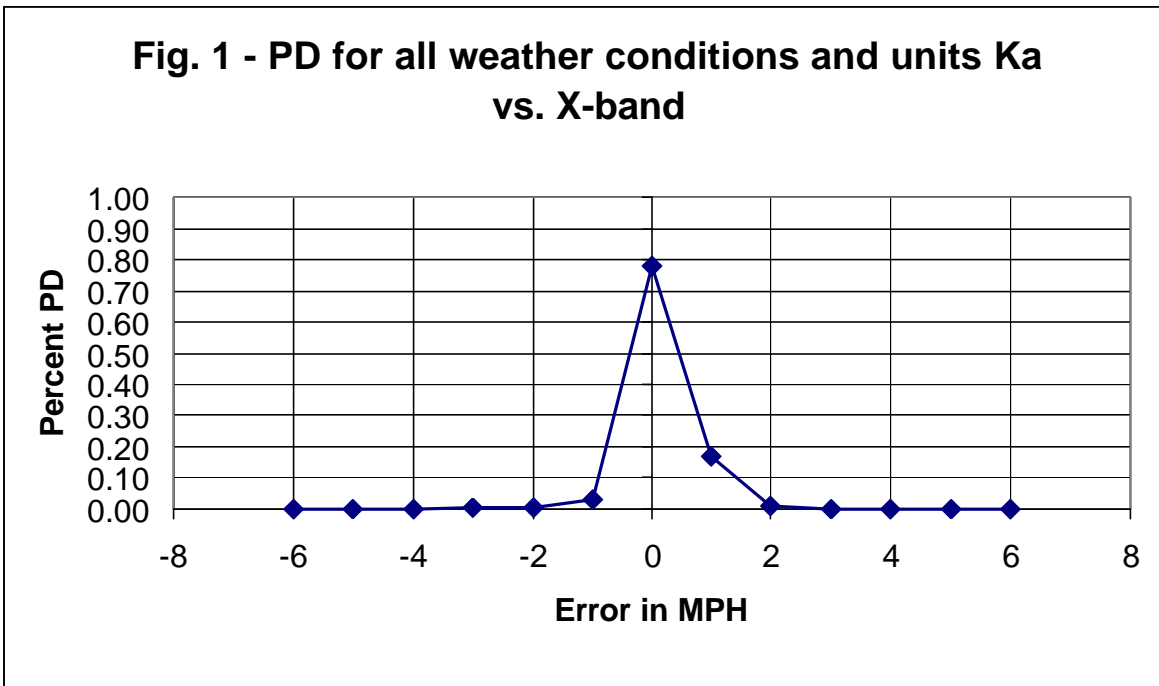
The relative characteristic and performance of available Ka-band radar units will also be investigated and documented.

New and innovative programs like the introduction of the Ka-band radar speed detection devices will enable the Division of State Police to enhance their speed enforcement program to better serve the motorists who travel New Jersey's highways.

#### 1. Progress this quarter by task:

- a) Examine the state of development of Ka-band Radar – A large portion of this task was completed in the first quarter. In this quarter we continued to search the literature for any new developments related to traffic radar and maintain contact with representatives of both Stalker and MPH to discuss the operation of their Ka-band radar and laser units. We also analyzed the relative merits of these two competitive radar systems.
- b) Prove/disprove Ka-band Radar is as reliable as X-band radar – We continued to implement the plan for the field testing of Ka-band radar units produced by Stalker and MPH formulated in the first quarter. An additional 400 measurements were made to bring the total number of measurements to the goal set in June of 1,000. 200 of these measurements were made from a moving vehicle; 100 with the MPH Ka-band radar unit (BEE-III) and 100 with the Stalker Ka-band radar unit. 200 additional measurements were taken under wet weather conditions from a stationary location; 100 with the MPH Ka-band radar unit and 100 with the Stalker Ka-band radar. These measurements were taken to add to our study of the effects of weather on Ka-band vs. X-band Doppler Radar performance. In all cases the Ka-band measurements were compared to the reference MPH K55 X-band radar unit.

- c) Statistically validate radar testing approaches – The results of the third quarter tests were consolidated with the data from previous quarters and statistically analyzed. The results of this analysis are shown in the following figures.



This figure shows the probability density (PD) of the difference between the reference X-band radar unit and the results obtained for both the Stalker and MPH Ka-band radar units under all weather conditions and includes both stationary and moving data. It can be seen that the agreement is excellent. Radar units are to be accurate within  $\pm 3$  mph with virtually no errors greater than 1 mph observed.

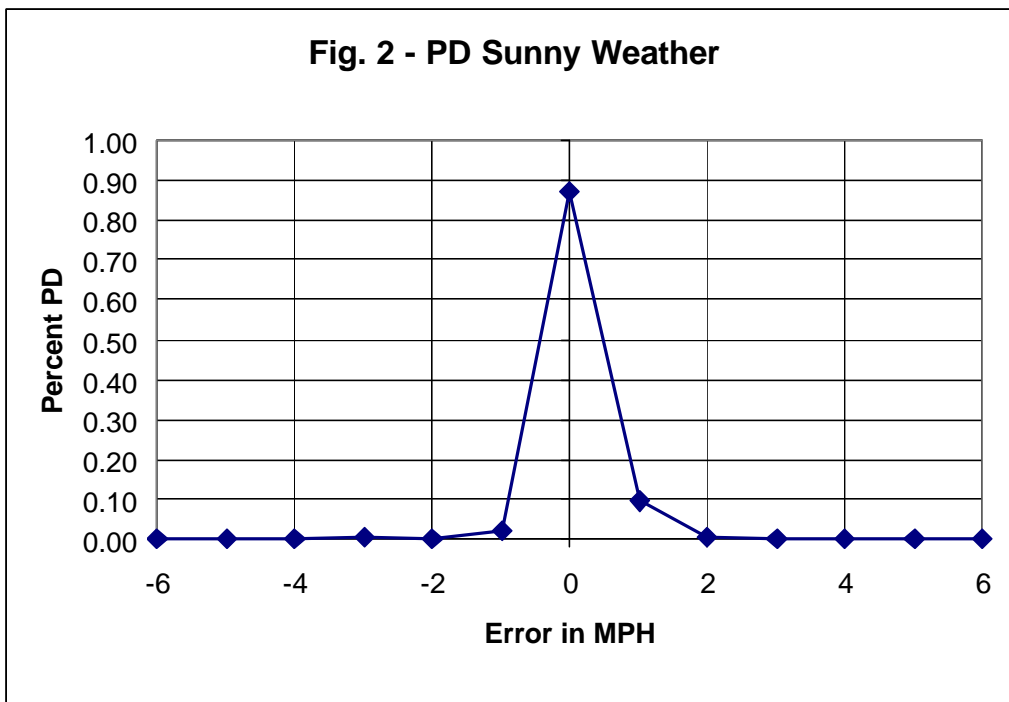


Figure 2 shows the PD for measurement during just fair weather conditions. As might be expected the results are even better than for the all weather conditions. The next graph, Figure 3, shows the results for cloudy/wet weather now based on both Stalker and MPH Ka-band radar measurements. Although slight less than for all weather, there is still excellent correlation between the X and Ku measurements. The accurate is still well within  $\pm 3$  mph with virtually no errors greater than 1 mph observed.

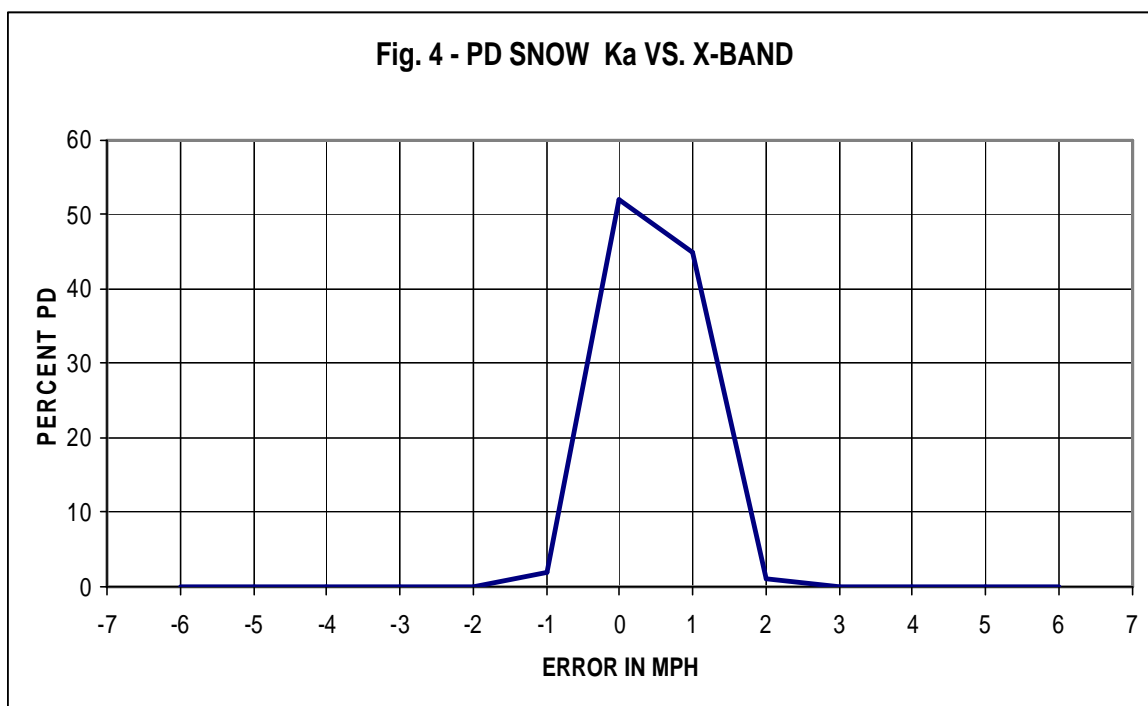
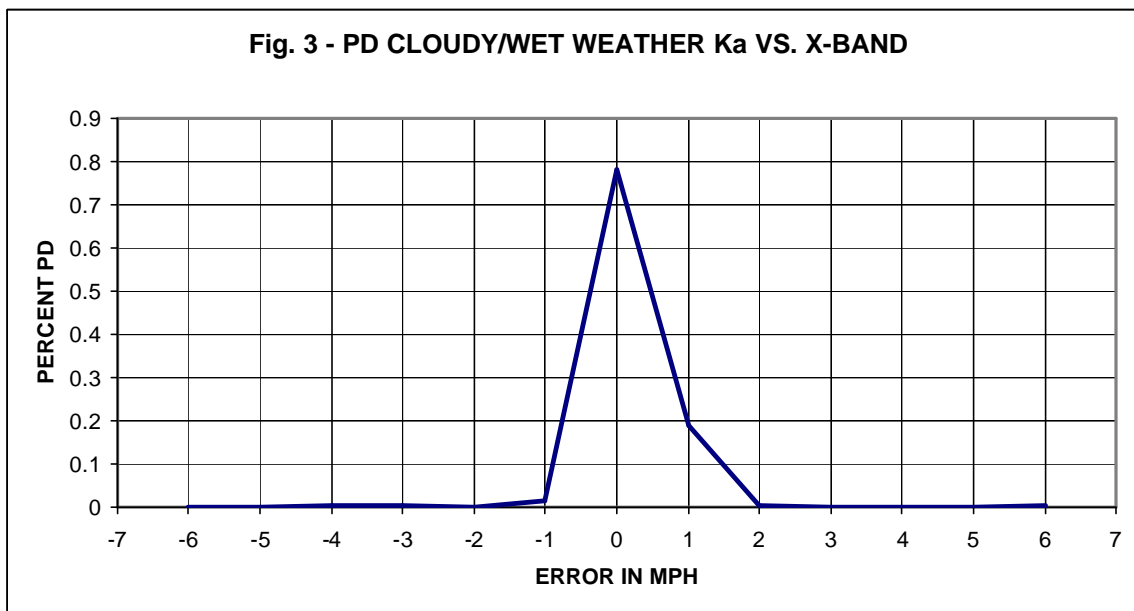
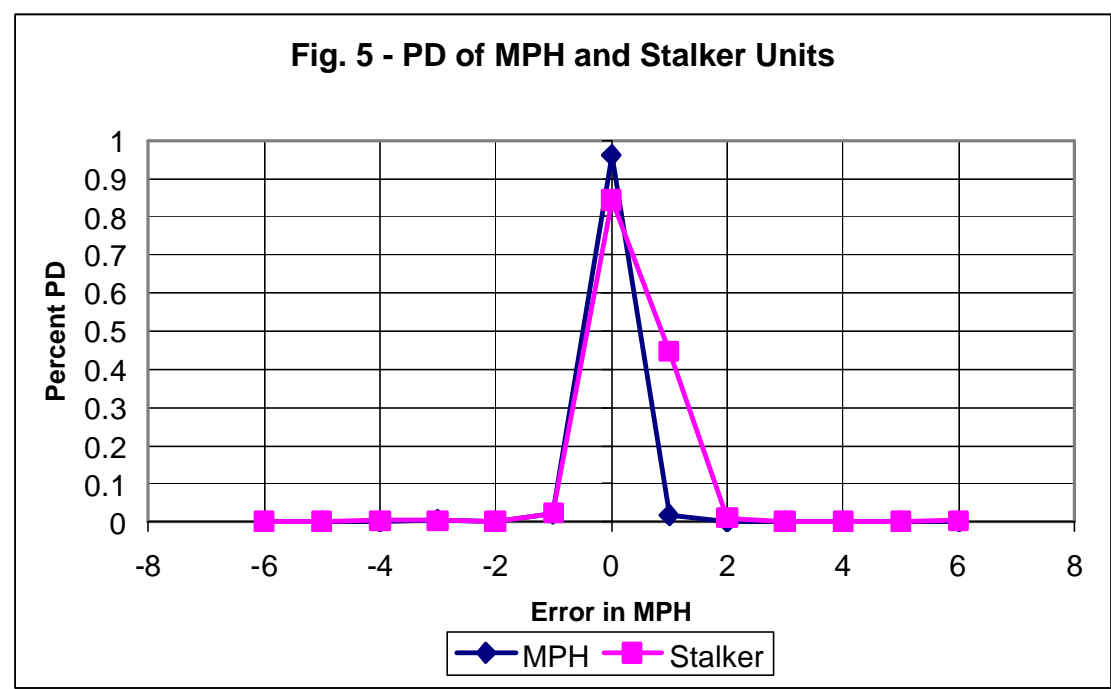


Figure 4 shows the effect of snow on the measurements. These results are based on only Stalker measurements as there has been no opportunity to get additional measurements

in snow. Based on the accumulated data, Dr. Guida sees no significant degradation at Ka-band in performance under different weather conditions.

Figure 5 shows a comparison of the measured performance of the Stalker and MPH Ka-band radar units in comparison the X-band K55 reference. Although the errors of the MPH appear slightly smaller, this difference is believed to be due to small calibration errors that cannot be totally eliminated. Both units performed well with in the specified measurement uncertainty. Differences were initially observed between the performance of the Stalker and MPH radars when vehicles traveling at low speeds, but were found during later testing. These results do not include measurements taken during motion.



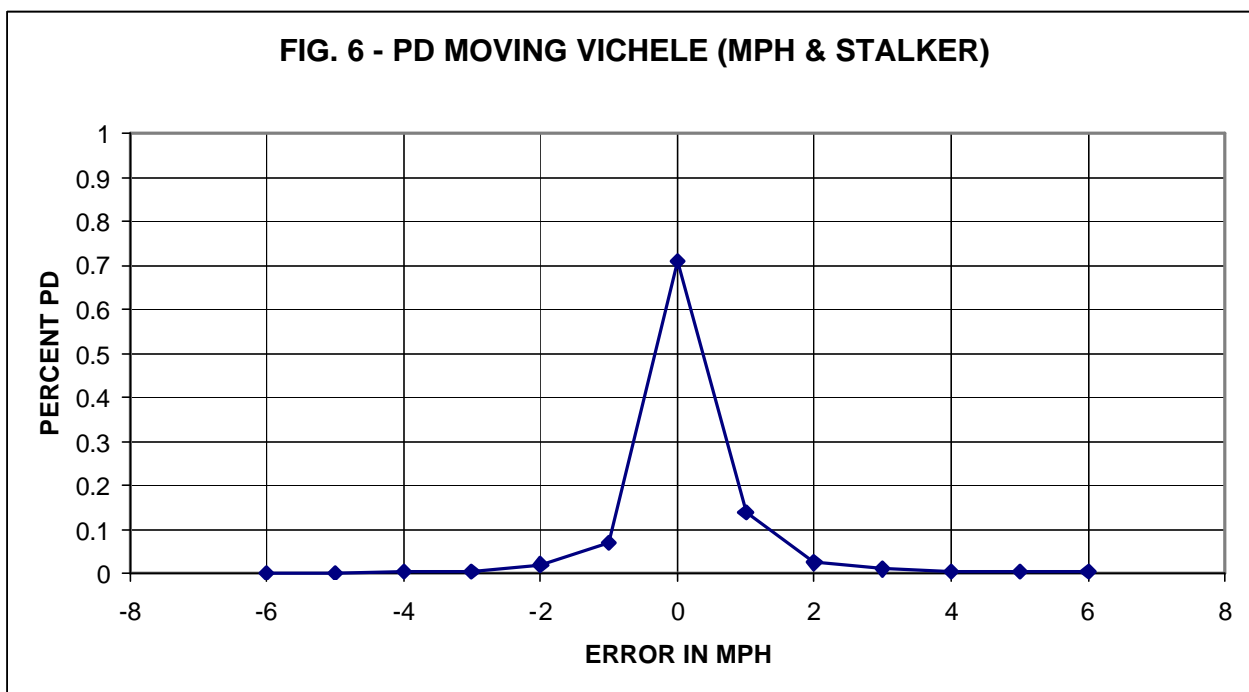


Figure 6 shows the results of measurements taken with both Stalker and MPH Ka-band radar units while in motion. Although these measurements show greater variance than stationary results, there is still good correlation between the X and Ku measurements. The accuracy is still well within  $\pm 3$  mph with virtually no errors greater than 1 mph observed. Included in these tests is a run of data with the MPH radar unit that showed greater deviation than any of the others. These results were included for completeness, but are believed to be an anomaly. Later testing with the same MPH radar unit showed excellent correlation,

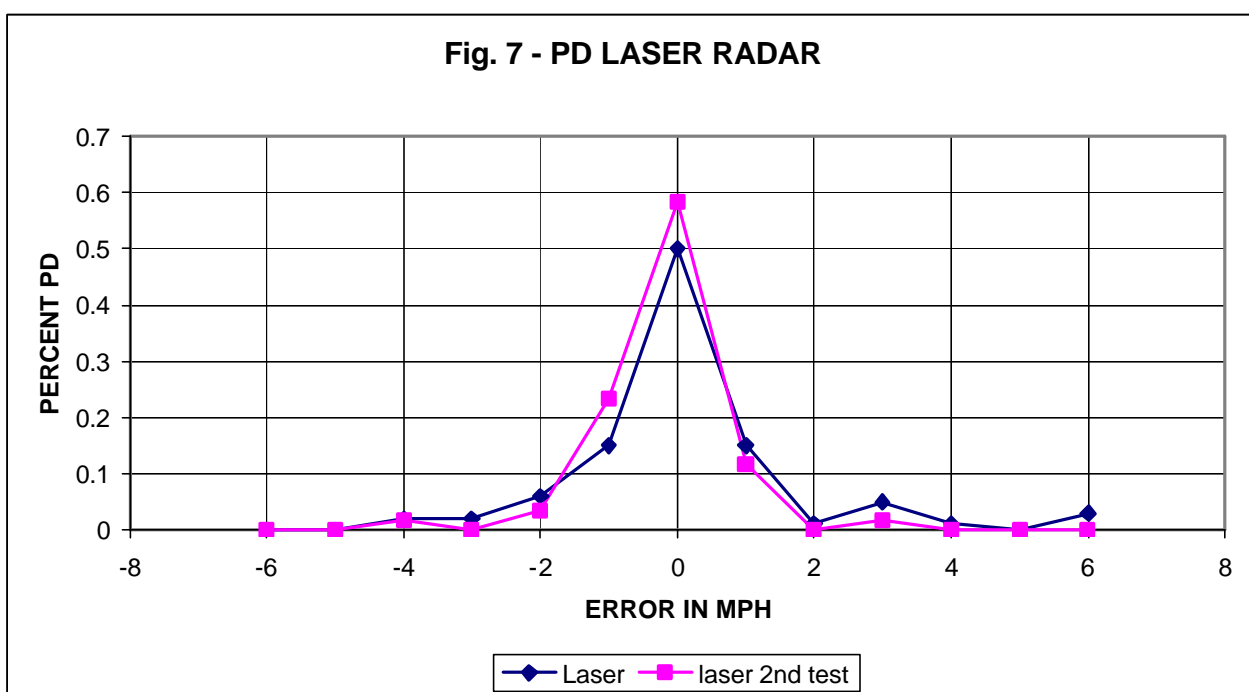


Figure 7 shows the results of testing with a laser radar unit. 100 measurements have been taken with 40 in the first set and 60 in the second set. Some learning is required to take accurate laser radar measurements as the operator must make certain that the laser unit is pointed at the same vehicle as the X-band radar is responding to. This complication is believed to be the reason for the greater variance displayed by the laser results. To illustrate this point both the overall laser results and these results with data from the initial test set removed are displayed in Figure 7. An almost 10 percent increase in zero error probability density is shown as a result of learning. Additional laser measurements are planned to provide a better metric of laser radar performance.

Figure 8 shows a laser radar test in progress. Two persons are required to perform this test. One outside the car with the laser radar unit, which must be normally operated out of the car, and a second person to read the X-band radar inside the car. The measurements must be synchronized to insure that the same vehicle is being measured by both units.



**Figure 8. TCNJ student Steve Mach taking a laser radar measurement.**

- d) Develop specifications for Ka-band radar that meet the requirements of the Court system – Work was begun on this objective in the last quarter. It is clear from the statistical results that both types of Ka-band radar will more than meet the accuracy requirements imposed by the law. The relative technical and operational merits of the Stalker and MPH Ka-band radar units have been reviewed. It was agreed that there are no significant differences between the measured performances of both units. The MPH displays a slightly smaller variance than the Stalker unit, but this difference could be due to small calibration errors that cannot be totally eliminated. All units performed well with in the specified measurement uncertainty ( $\pm 3$  MPH). The Stalker radar offers the advantage of simultaneously displaying the speed of vehicles located both in front and in back of a patrol car. The MPH radar displays

either, but requires the operator to manually switch the display from one direction to the other. The MPH is slightly smaller in size. A meeting with the Attorney General's office is planned to determine how to best formulate these requirements. Due to vacation schedules this meeting has been delayed to October.

- e) Examine the state of development for Laser-band Radar – A search of Laser based radar literature has been completed in the last quarter. We have also been in contact with some of the manufacturers of laser based radar. We now have 100 laser radar measurements and plan to take additional measurements during the last quarter to complete this task.

## 2. Proposed activities for next quarter by task

- a) Examine the state of development of Ka-band radar -- This part of the study has been essentially completed. Minimal effort is planned for the final quarter.
- b) Prove/disprove Ka-band Radar is as reliable as X-band radar – This task is essentially complete. We may take a few additional in motion measurements during the last quarter, but all measurement objectives have been completed (MPH evaluation during cloudy/wet weather conditions, in motion measurements of both MPH and Stalker). The analysis of the effects of weather on Ka-band vs. X-band Doppler radar performance will be continued.
- c) Statistically validate radar testing approaches – The results of the third quarter tests have been statistically analyzed. Some additional analysis is planned with regard to the effects of motion and weather.
- d) Develop requirements for Ka-band radar meeting requirements of the Court System – Meetings with the Deputy Attorney General (John J. Dell' Aquilo) is planned for October. Much of the effort in the fourth quarter will be focused on this task.
- e) Examine the state of development for Laser-band radar – Additional laser radar system testing is planned for October and possibly early November. Our goal is to have over 200 laser measurements.

## 3. List of deliverables provided in this quarter by task (product date):

- a) Second Quarterly Report – was completed on 9/27/07
- b) Monthly reports – It was agreed that meeting minutes would be used in place of monthly reports and were completed on 7/11/07, 8/13/07 and 9/21/07 respectively. These minutes are in Appendix I.

## 4. Progress on Implementation and Training Activities: Not applicable to this project.



5. Problems/Proposed Solutions: None. Desired evaluation of laser radar units was voluntarily accepted as part of this research project.

## 6. Invoice Summary

### Invoice Summary Page

<u>Task No.</u>	<u>Task Description</u>	<u>Percent of Total Project Budget</u>	<u>Total Project Cost</u> \$ 49,837.00	<u>% of task this quarter</u>	<u>Cost this quarter</u>	<u>% of task to date</u>	<u>Total Cost to date</u>
	Literature Search	5%	\$2,491.85	0%	\$0.00	100%	\$2,491.85
1	Examine the state of development of Ka-band Radar	10%	\$4,983.70	5%	\$249.19	95%	\$4,734.51
2	Prove/disprove Ka- band Radar is as reliable as X- band radar	30%	\$14,951.10	30%	\$4,485.33	90%	\$13,436.43
3	Statistically validate radar testing approaches	25%	\$12,459.25	30%	\$3,737.78	90%	\$11,201.47
4	Develop specifications for Ka-band radar meeting requirements of the Court system	10%	\$4,983.70	10%	\$498.37	30%	\$1,495.11
5	Examine the state of development for Laser- band Radar	10%	\$4,983.70	50%	\$2,491.85	80%	\$3,986.85
	Final Report	10%	\$4,983.70	0%	\$0.00	0%	\$0.00
		100%	<b>\$49,837.00</b>		<b>\$11,462.51</b>		<b>\$37,374.49</b>

## 7. Summary:

- Examined the state of development of Ka-band Radar – Essentially completed last quarter.
- Data shows Ka-band radar is as reliable as X-band radar – 1,000 Measurements taken that show Ka-band accuracy within  $\pm 3$  mph with virtually no errors > than 1 mph. Additional measurements were taken in different weather conditions and with the radar units in motion.
- Statistically validated radar testing approach – The results of the first, second and third quarter tests were consolidated and statistically analyzed.
- Examine the state of development for Laser-band radar – 200 laser radar measurements have been taken.
- Status - Project is on schedule and budget, and proceeding as planned.

## 8. Appendix I Meeting Minutes

### **Ka-band Radar Research Meeting Minutes, July 11, 2007**

Present: Sgt. Greg Williams, NJ State Police; Dr. Allen Katz, TCNJ/LTI; Steve Mack, TCNJ Student and Dr. Allan Guida, LTI

This meeting was held at the offices of Linearizer Technology to review the project status and plans.

1. Sgt. Williams reported that he had been asked if it would be possible to complete the data gathering by the end of the summer. It appears that the car in which the Ka-band radar equipment is installed is needed for another application. The need for additional measurements with the Stalker Ka-band radar and the MPH Ka-band radar particularly during cloudy/wet weather conditions was discussed. It was felt that an additional 300 to 400 measurements could be completed by the end of August. The only impediment would be the lack of suitable weather. Dr. Guida observed that a total of 1,000 measurements should be more than sufficient for the statistical analysis.
2. Sgt. Williams asked about the need for measurements from a moving vehicle. All felt that such measurements should be included in the study. Dr. Katz noted that students were available to assist with the measurements and that their presence could speed the measurement process.
3. Sgt. Williams also noted that obtaining data on the performance of Laser radar was also important. These measurements can be taken from any radar equipped police car and thus could be taken after the present car is returned, but there is interest in obtaining this information as soon as possible.
4. It was agreed that the project focus should be on obtaining additional measurements during the remainder of July and the month of August. The goal will be the completion of a total of 1,000 Ka-band radar measurements by the beginning of September. In addition it would be desirable to make some moving measurements (100 or more) before use of the present car is lost. An attempt will also be made to take some Laser radar measurements during this period.
5. Sgt. Williams reported that as of July 21, 2007 the Traffic Bureau will be renamed Operations Safety Bureau and his title will change to the Squad (Supervisor) Leader for the Safe Passage Corridor Unit, Analysis Squad.
6. A date for the next meeting was not set, but it should be before the second week of August to review measurement progress.

### **Ka-band Radar Research Meeting Minutes, August 13, 2007**

Present: Sgt. Greg Williams, NJ State Police; Dr. Allen Katz, TCNJ/LTI; Joe Hietman, TCNJ Student and Dr. Allan Guida, LTI

This meeting was held at the offices of Linearizer Technology to review the project status and plans.

1. Sgt. Williams reported that the need to complete the data gathering by the end of the summer had lessened. It now appears that he can continue to use the car in which the Ka-band radar equipment is installed during September and possibly longer. However, his goal is still to complete the bulk of the measurements by the end of August.
2. Sgt. Williams reported that he had taken advantage of some of the wet weather in July to add 100 measurements with the MPH Ka-band radar during cloudy/wet weather conditions.
3. Sgt. Williams also reported that with the assistance of TCNJ student Steve Mack that 40 laser radar measurements were taken. He recommended that these measurements, the first with the laser radar, be considered preliminary as he and Steve were learning how to synchronize the X-band and laser measurements. Timing is more critical with the laser unit because of its very narrow beamwidth. The laser radar can be focused on a different vehicle than the X-band radar, which responds to the strongest reflection.
4. Sgt. Williams will be on vacation the following week, but plans to begin taking moving radar measurements after he returns. Steve Mack will be away at this time, but Joe Hietman will be available to assist with the measurements during this time period. It was agreed that Joe would begin assisting Sgt. Williams on Thursday August 23<sup>rd</sup>.
5. Dr. Katz reported that he and Dr. Guida would begin analyzing the new data during the coming week.
6. A date for the next meeting was not set, but it should be before the second week of September. Dr. Katz noted that TCNJ classes begin on August 28<sup>th</sup>.

### **Ka-band Radar Research Meeting Minutes, September 21, 2007**

Present: Sgt. Greg Williams, NJ State Police; Dr. Allen Katz, TCNJ/LTI and Dr. Allan Guida, LTI

This meeting was held at the offices of Linearizer Technology to review the project status and plans.

1. Sgt. Williams reported that he is a little behind schedule because of being involved in training for a week. He has completed 260 additional measurements: 100 moving measurements with the MPH Ka-band radar, 100 moving measurements with the Stalker Ka-band radar, 100 stationary measurements in light rain with the Stalker Ka-band radar, and 60 measurements with a laser radar unit.
2. 100 laser radar measurements have now been completed. Sgt. Williams noted that it take some learning to make the laser radar measurements as the operator must make certain that the laser unit is pointed at the same vehicle as the X-band radar is responding to. This factor, which was discussed at the last meeting, may explain some of the discrepancies between the X-band and laser measurements.

3. Dr. Katz reported that he and Dr. Guida has completed the statistical analysis of the previous data and will work have the analysis of the current data completed in time for inclusion in the third quarter report.

4. The relative technical and operational merits of the Stalker and MPH Ka-band radar units were discussed. It was agreed that there are no significant differences between the measurement performance of both units. The MPH displays a slightly smaller variance than the Stalker unit, but this difference could be due to small calibration errors that cannot be totally eliminated. All units performed well with in the specified measurement uncertainty (+/- 3 MPH). The Stalker radar offers the advantage of simultaneously displaying the speed of vehicles located both in front and in back of a patrol car. The MPH radar displays either, but requires the operator to manually switch the display from one direction to the other. The MPH is slightly smaller in size.

5. The need to schedule a meeting with the Attorney General's office was discussed. Dr. Katz observed that we are behind schedule on this phase of the project. Sgt. Williams has been in contact with the Attorney General's office. He noted that we need to meet with the Deputy Attorney General (John J. Dell' Aquilo), but he is away on vacation and will not return until Oct. 14. He has responded to our e-mails and has agreed to a meeting after he returns.

6. Sgt. Williams requested that Dr. Katz send him a summary stating the status of the project. Sgt. Williams will use this summary to formulate a memo to State Police Major H. Scripture stating that with the majority of measurements complete that the Ka-band Radar units we have been testing provide an accurate measure of vehicle speed. Dr. Katz agreed to send this summary.

7. Support for the Texas Transportation Research Project Team's visit was discussed. Sgt. Williams reported that this project is in Lt. Brian Crain's of the Construction Unit area of responsibility. Dr. Katz said that he could supply student support, if they would be of assistance.

8. Our next meeting will be on Sept. 27<sup>th</sup> at 10 AM at the Department of Transportation MOB research Office. Our third quarter report will be presented at this meeting.